Case Series
TMJ Disorders

Minimally invasive intraoral condylectomy: proof of concept report

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Abstract. A significant proportion of facial asymmetry cases are caused by abnormal growth of the mandibular condyles. Surgical management is generally based on a condylectomy performed through a pre-auricular transcutaneous access. However, this approach entails potential neurovascular, salivary, and aesthetic complications. In this study, a proof-of-concept evaluation was performed of a novel minimally invasive technique for condylectomy performed through an intraoral approach. Based on precise three-dimensional virtual planning to define intraoperative references, this technique provides an excellent access for total or partial condylectomy through a limited intraoral incision. Piezoelectric surgery with customized attachments enables the safe, accurate execution of the condylectomy. In addition, experience gained in seven consecutive cases suggests that the need for coronoidectomy can be obviated, surgical time is reduced to an average of 16.9 min, and postoperative morbidity is minimal. This alternative intraoral approach could become the treatment of choice for most condylar hyperplastic conditions.

Generically, condylar hyperplasia (CH) refers to any condition capable of enlarging the mandibular condyle, thereby affecting the size and morphology of the mandible, altering the occlusion, and indirectly affecting the maxilla.[1] A symmetric or most often asymmetric dentofacial deformity can develop as a result. Treatment entails temporomandibular joint (TMJ) surgery to address the underlying pathological condition in the condyle and subsequent or concomitant orthognathic surgery to restore facial harmony and re-establish a functional occlusion.

The conventional approach to the mandibular condyle consists of an extraoral access through a pre-auricular incision.[2–8] This extraoral approach provides excellent visualization of the condyle, condylar neck, and glenoid fossa. Moreover, additional anatomical exposure can be gained by temporal extension, zygomatic arch sectioning, or combination with a submandibular approach.[2,9,10] Due to the proximity to vital anatomical structures, this approach entails a risk of neurovascular complications or salivary fistulae.[5,11–15] It is technically complex, time-consuming,

and requires a certain degree of surgical expertise. In addition, the use of an external transcutaneous incision can result in unaesthetic scarring.[11,15]

As an alternative to this extraoral approach, an intraoral access to the condyle is possible.[11,13,15,16] This intraoral approach minimizes the risk of facial nerve injury and salivary fistulae, and visible facial scars are avoided completely.[11,13,15–17] Hence, a rapid postoperative recovery and high patient satisfaction are to be expected. Despite these advantages, the popularity of this approach, as reported in the scientific literature, is

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comparatively low. This is probably due to the lack of a comprehensive description of the surgical technique and the absence of precise treatment planning criteria.

A minimally invasive surgical protocol for intraoral condylectomy is described herein. This novel technique is based on precise three-dimensional (3D) treatment planning and piezoelectric surgical resection of the condylar process using customized attachments. A comprehensive analysis of the authors' preliminary experience with seven consecutive cases is presented as a proof-of-concept demonstration of the feasibility, efficiency, and safety of this technique.

Patients and methods

All patients with facial asymmetry due to abnormal condylar growth, who underwent condylectomy via an intraoral approach at a specialized centre for the treatment of dentofacial deformities, were evaluated prospectively. The Declaration of Helsinki guidelines on medical protocol and ethics were followed at all stages of treatment. The performance of this study did not alter the ethically approved protocol for the diagnosis and treatment of facial asymmetry at the study centre and hence was exempt from the requirement for further ethical approval.

Diagnostic workup and treatment planning

After a detailed interview and thorough clinical assessment, the imaging protocol for facial asymmetry at the study institution was followed. This protocol includes: (1) technetium 99m (^{99m}Tc) scintigraphy, in order to investigate active condylar growth, and (2) cone beam computed tomography (CBCT) (i-CAT version 17–19; Imaging Sciences International, Hatfield, PA, USA) in maximum mouth opening position, in order to evaluate the condylar morphology and the translation in maximum inter-incisal opening. The study centre's standardized scanning protocol for dentofacial deformity patients was used. This protocol comprises vertical (sitting upright) scanning in the 'extended field' mode (field of view (FOV) 17 cm diameter and 22 cm height, scan time 7 s, voxel size 0.4 mm) at 120 kV and 5 mA. Patients were instructed to sit upright and position themselves in natural head position (NHP).

Primary CBCT images were stored as 576 DICOM (Digital Imaging and Communications in Medicine) data files. These were segmented manually and processed using third-party software (SimPlant Pro OMS; Materialise Dental, Leuven, Belgium). A 3D skull model reconstruction was obtained (Fig. 1). The prospective level and orientation of the ostectomy were planned according to the underlying diagnosis and the adjacent anatomical structures, respectively (Fig. 2). A high condylectomy was planned for an anatomically normal condyle, whereas a low condylectomy (at the junction of the condylar head and neck and preserving the condylar neck) was planned for benign tumours.

Scanning in maximum mouth opening enabled the surgeon to determine whether the amount of condylar translation in maximum opening would be clearly sufficient to enable the planned resection through an intraoral approach. In addition, the anatomical relationship to the coronoid process was evaluated in terms of potential interference with the surgical access.

Surgical technique

Under general anaesthesia and nasotracheal intubation, maximum mouth opening was forced with a Molt mouth gag fitted with silicone tubing to avoid dental injuries.

A 2-cm vertical incision was made along the anterior border of the ascending mandibular ramus. This incision is similar to that used for a sagittal split osteotomy. Sub-periosteal dissection proceeded cranially towards the coronoid process and then deeply towards the sigmoid notch. The temporalis tendon was dissected from the anterior, lateral, and medial border of the ramus up to the level of the sigmoid notch (Fig. 3). The superior temporalis attachment on the coronoid process above the level of the mandibular notch was preserved completely. If required, a coronoidectomy was performed at this stage using a piezoelectric microsaw (Implant Center 2; Satelec-Acteon Group, Tuttlingen, Germany).

The sub-periosteal dissection along the condylar neck and head was continued up to the inferior joint space, such that the
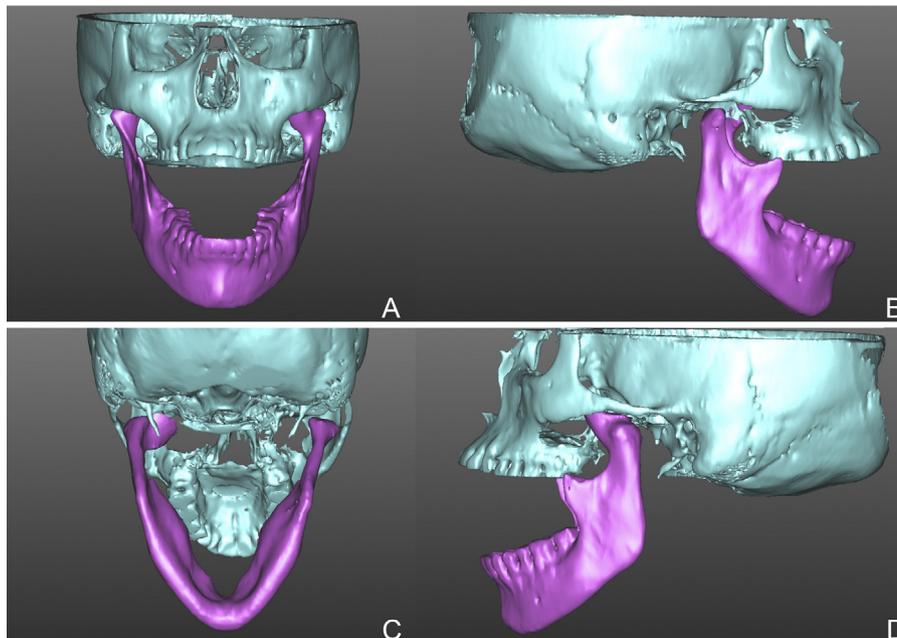

Fig. 1. Three-dimensional skull model in maximum mouth opening. Frontal (A), right profile (B), inferior (C), and left profile (D) views.
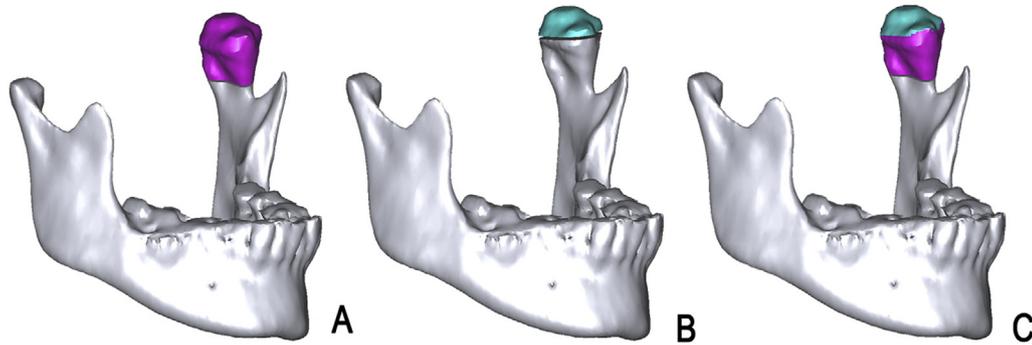
Fig. 2. Treatment planning of the prospective level and orientation of the ostectomy. A low condylectomy (A), high condylectomy (B), and superimposition of both treatment plans (C) are shown. A low condylectomy (A) was performed in this patient.

disc was not disrupted. The same micro-saw was used to execute a condylectomy at the planned level and with the anticipated angulation. A specific extra-long customized instrument with a short angulated tip was used for this purpose (Fig. 4).
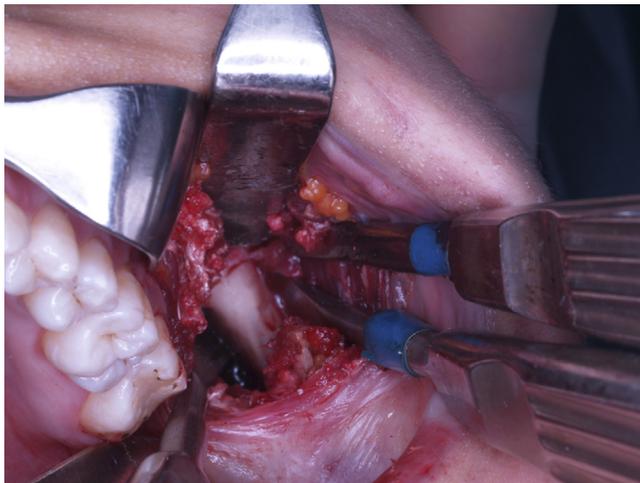

Fig. 3. Sub-periosteal dissection. The temporalis tendon is dissected off the anterior, lateral, and medial borders of the ramus up to the level of the sigmoid notch, with preservation of the superior temporalis attachment on the coronoid process above the level of the mandibular notch.

Fig. 4. Extra-long piezoelectric surgery instrument.

This device enables the surgeon to reach the condylar neck from an intraoral access comfortably while minimizing the soft tissue dissection and allowing a steady execution of the ostectomy. The articular capsule and lateral pterygoid muscle were dissected off the condylar head and neck. At this point, stabilization of the condylar fragment with a temporary screw and wire can facilitate the soft tissue dissection (Fig. 5). After intraoral delivery of the osteotomized fragment, a tension-free watertight soft tissue closure was performed with resorbable 4–0 polyglactin (Vicryl; Ethicon, Somerville, NJ, USA) (Fig. 6). No drainage tubes were left in place.

Endoscopic assistance may be used throughout the surgical intervention to improve illumination and visualization of the surgical field.

Patients were discharged from the hospital the following day. Average postoperative pain was evaluated on a visual analogue scale (VAS), with a range of 0 (no pain) to 10 (worst pain imaginable). Active physiotherapy was started 3–4 days after surgery to accelerate functional recovery and prevent joint ankylosis.

A complete case example is shown in Fig. 7.

Results

From August 2014 to January 2016, seven patients underwent an intraoral condylectomy at the study centre due to progressive facial asymmetry. The patient demographic characteristics, clinical findings, surgical procedure, pathology results, and postoperative pain levels are summarized in Table 1. Active condylar growth was detected in all cases. The affected joint was on the left side in all patients except one. The underlying cause of the abnormal condylar growth was Wolford CH type 1 in two cases and CH type 2 in the other five.[1]

Chronologically, the first two cases were operated on under endoscopic assistance, and a coronoidectomy was performed in both. In the remaining cases, direct illumination of the surgical field with a headlight was deemed sufficient, and resection of the coronoid process was
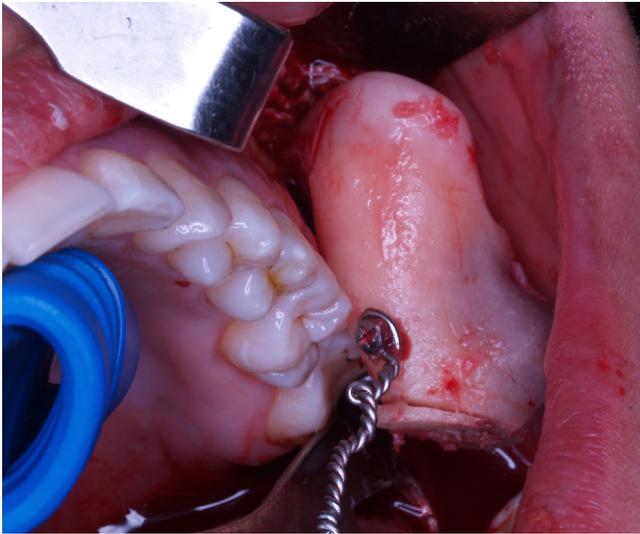
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Fig. 5. Temporary stabilization of the condylar fragment with a screw and wire.

obviated. The average duration of surgery from incision to last suture was 16.9 min (range 14–25 min). A progressive reduction in the operation time was observed chronologically from case 1 to case 7.

Postoperative swelling was minimal in all cases. No other complications occurred. The average postsurgical pain on the VAS was 1 (range 0–2). The facial asymmetry was improved markedly immediately after surgery, and a normal, painless maximum mouth opening could be achieved within 48 h with active physiotherapy.

Orthodontic treatment to prepare for subsequent orthognathic surgery was initiated between 1 and 2 weeks after surgery. To date, four patients have undergone orthognathic surgery. The timing of surgery was scheduled according to a 'surgery late' protocol (conventional full orthodontic preparation) in three cases and

Table 1. Patient demographic characteristics, clinical findings, surgical procedure, pathology results, and postoperative pain level.

Patient	Age, years	Sex	Clinical findings	Affected side	Coronoidectomy	Endoscopic assistance	Duration of surgery (min)	Pathological findings	Postop. pain (VAS)
1	29	F	Progressive facial asymmetry Chin deviation to the right Ipsilateral and anterior open bite, contralateral crossbite Normal mouth opening	Left	Yes	Yes	25	CH 2	1
2	25	M	Progressive facial asymmetry Chin deviation to the right Ipsilateral open bite Normal mouth opening	Left	Yes	Yes	19	CH 2	2
3	32	F	Progressive facial asymmetry Chin deviation to the right Ipsilateral open bite, contralateral crossbite Normal mouth opening	Left	No	No	16	CH 1	0
4	22	F	Progressive facial asymmetry Chin deviation to the right Ipsilateral and anterior open bite, contralateral crossbite Normal mouth opening	Left	No	No	14	CH1	0
5	42	F	Progressive facial asymmetry Chin deviation to the right Ipsilateral and anterior open bite, contralateral crossbite Normal mouth opening	Left	No	No	15	CH 2	2
6	28	F	Progressive facial asymmetry Chin deviation to the left Contralateral crossbite Normal mouth opening	Right	No	No	15	CH 2	0
7	38	F	Progressive facial asymmetry Chin deviation to the right Ipsilateral open bite, contralateral crossbite Normal mouth opening	Left	No	No	14	CH 2	2

Postop., postoperative; VAS, visual analogue scale (range 0–10); F, female; M, male; CH 1, condylar hyperplasia type 1; CH 2, condylar hyperplasia type 2 (osteochondroma).
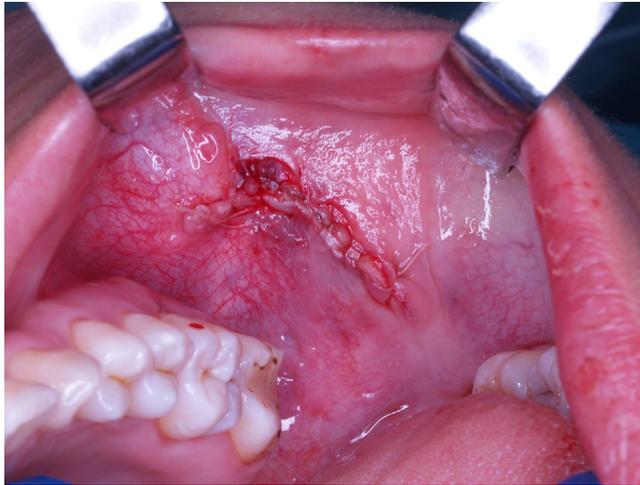
Fig. 6. Wound closure.

a 'surgery early' protocol in one.[18] No recurrence of facial asymmetry has been observed over an average follow-up of 8.7 months (range 2–16 months).

Discussion

In 2013, Wolford proposed a classification system for CH covering all conditions that lead to excessive growth and enlargement of the mandibular condyle and which are therefore potential causes of alterations in the bony architecture of the mandible, malocclusion, and dentofacial deformity.[1] This classification is comprehensive but simple and reflects well the clinical and imaging characteristics, occurrence rate, natural progression, histological particularities, and recommended treatment. In brief, CH type 1 refers to accelerated
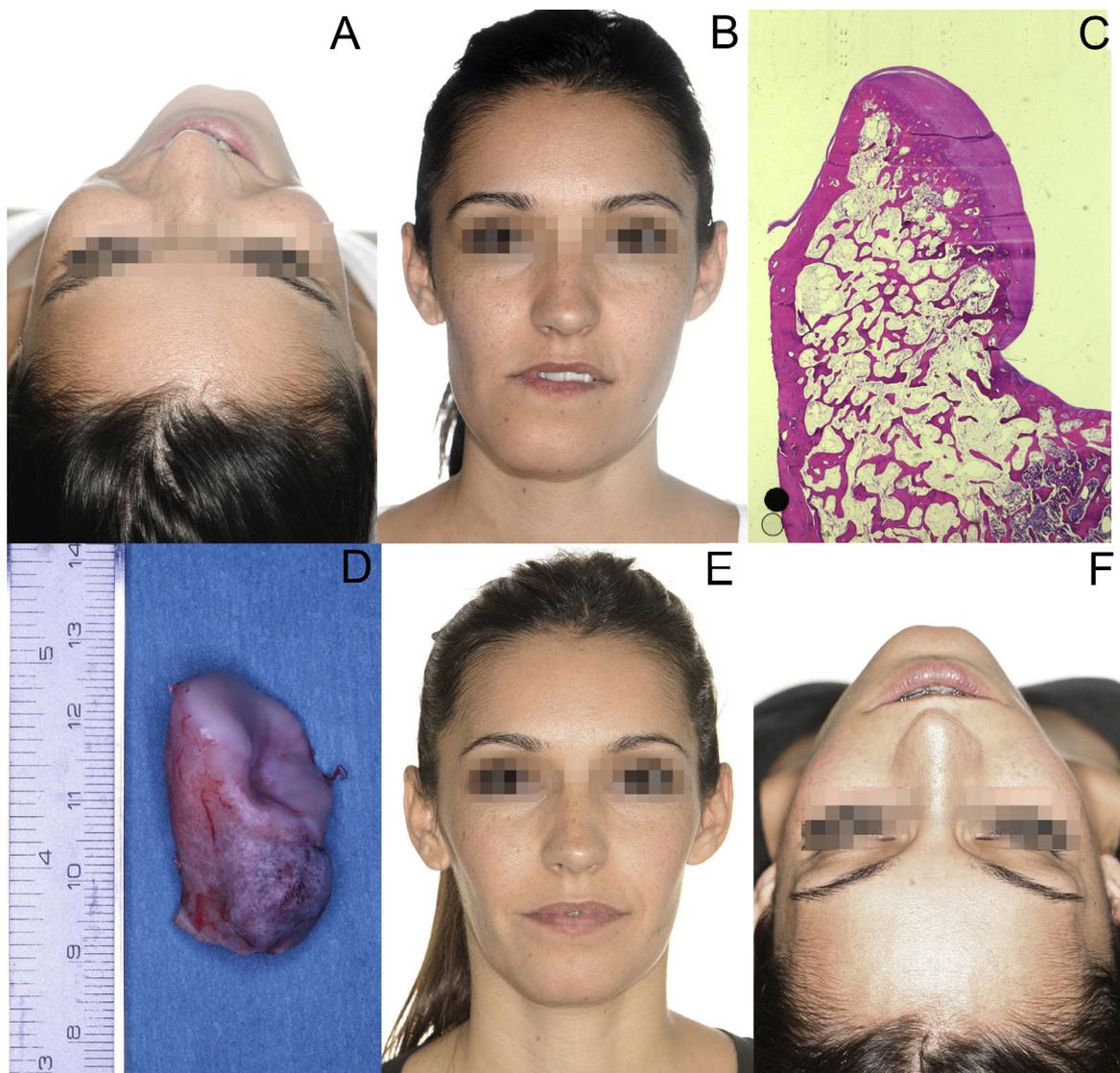

Fig. 7. Facial and pathology images of the patient shown in Figs 1–6. (A) and (B) are preoperative images. (C) and (D) show the pathological analysis, which was compatible with condylar osteochondroma. (E) and (F) show the patient at 3 weeks after surgery.

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and prolonged 'normal' growth, CH type 2 corresponds to osteochondroma, CH type 3 includes other types of benign condylar tumours, and CH type 4 comprises malignant condylar tumours.

At the authors' institution, the treatment protocol for facial asymmetry due to CH includes interruption of abnormal condylar growth with a condylectomy and second-stage correction of facial asymmetry with orthognathic surgery. If the patient has completed growth and systemic conditions allow, first-stage surgery is performed as soon as the diagnosis of excessive condylar growth is established. Although it is to be expected that the sooner the condylar growth is normalized the less facial deformity will develop and thus the easier secondary corrective orthognathic surgery will be, in adolescents it seems reasonable to wait for complete contralateral mandibular growth.

The conventional and most common surgical approach to the mandibular condyle is through a pre-auricular incision.[2–8] This approach provides ample exposure of the TMJ hard and soft tissue components and can easily be extended to allow additional exposure of the adjacent anatomical structures.[2,9,10] However, visible unaesthetic facial scars, paresis of the temporal and zygomatic branches of the facial nerve, and salivary fistulae are significant potential complications.[5,11–15] As an alternative, access to the mandibular condyle from an intraoral approach is possible due to condylar translation in maximum mouth opening. This approach minimizes the incidence of neurovascular and salivary complications, avoids the creation of facial scars, and preserves the integrity of the articular capsule, thereby reducing the risk of fibro-osseous TMJ ankylosis.[11,13,15,16] Moreover, taking into account that osteochondromas grow anteromedially in most cases,[8,13] an intraoral approach provides a more direct path to the tumour with less tissue dissection.[11,13] Overall, these advantages result in minimal patient morbidity.[11,13,15,16]

The intraoral route to the mandibular condyle can be contextualized within the current trend for minimally invasive procedures that enable expedited postoperative recovery, and the preferential use of natural orifices for surgical access. It represents the maxillofacial counterpart to the so-called NOTES (natural orifice transluminal endoscopic surgery) in gastrointestinal surgery and interventional gastroenterology. This emerging field in which a scar-less access to the peritoneal cavity is gained via a hollow viscus (mouth, stomach, colon, anus, vagina, urethra, or cystic cavities)

has already been used for a variety of diagnostic explorations of the peritoneal cavity, as well as complex organ resections.[19] Potential advantages include the lower anaesthesia requirements, faster recovery and shorter hospital stay, and avoidance of the potential complications of external wounds (including unaesthetic scars and infections).[20]

In this proof-of-concept evaluation of the feasibility of intraoral condylectomy, endoscopic assistance was used in only two cases. Although the spatial orientation and perception of depth can be somewhat difficult in inexperienced hands, the use of an endoscope improves illumination of the surgical field, provides a magnified visualization of the TMJ for the whole surgical team, and may be a useful adjunct, especially for young surgeons. Nevertheless, direct visualization from the surgeon's intraoral viewpoint is sufficient for a safe and accurate execution of the procedure.

The key issue in determining whether a mandibular condylectomy is feasible through an intraoral access is the degree of condylar translation with mouth opening. To this effect, CBCT scanning of the patient in maximum mouth opening was performed. It may be argued that condylar movement can be simulated with treatment planning software, but the authors believe that virtual simulation of condylar rotation and translation is too inaccurate unless sequential scanning at different degrees of mouth opening is performed; however, this practice would be contraindicated ethically.

Additional benefits of 3D virtual planning for the intraoral condylectomy include the determination of the prospective level and orientation of the ostectomy and the potential need for a concomitant coronoidectomy. Regarding the former, it must be noted that, in comparison to other surgical procedures in which 3D planning involves the fabrication of CAD/CAM surgical guides or splints, the authors' virtual planning protocol for intraoral condylectomy does not result in the production of any type of surgical guide. Therefore, the intraoperative design of the condylectomy is not exact but approximate. However, virtual simulation of the level and orientation of the bone cut according to the underlying diagnosis and adjacent anatomical structures helps the surgeon to anticipate each situation individually and precisely.

Although at the beginning of the authors' learning curve an additional coronoidectomy was performed, experience has shown that resection of the coronoid process may be unnecessary. As corroborated with CBCT imaging in maximum

mouth opening, full condylar translation provides an adequate obstacle-free route to the condyle without interference from the coronoid in most cases. Furthermore, the anteromedial location of most osteochondromas[8,13] implies excellent exposure of the tumour without the need for coronoidectomy. Increasing surgical experience and the avoidance of coronoidectomy enabled the operative time to be reduced to an average of 16.9 min. Together with a minimally invasive surgical technique, the reduced theatre time was probably responsible for the patients' rapid and uneventful recovery and the low levels of postoperative pain.

It is a general perception that the type of condylectomy should be individualized according to the underlying diagnosis. While CH types 3 and 4 call for an individualized treatment plan according to tumour size and histology, most authors agree that the proliferative zone in CH type 1 can be eliminated adequately with a high condylectomy.[1] In CH type 2, the recommended height of the condylectomy continues to be the subject of debate. A review of the scientific literature found that most osteochondromas were managed with a total condylectomy,[8] but proponents of a more conservative approach refer to the benign nature of the lesion and avoiding TMJ reconstruction to justify a low condylectomy. In a retrospective cohort study of 37 osteochondroma cases with postoperative follow-up averaging 48 months (range 12–288 months), no recurrence occurred after a low condylectomy.[21] The surgical protocol developed by Wolford included ipsilateral reshaping of the condylar neck with disc repositioning and contralateral disc repositioning – when displaced – via a pre-auricular access, and concomitant orthognathic surgery.[21] In the present study, the selected level of resection for the two CH type 2 cases was a low condylectomy. No additional TMJ procedures were performed. Ongoing follow-up will confirm whether the positive results obtained are maintained in the longer term.

In conclusion, compared to the conventional pre-auricular access, an intraoral approach to the mandibular condyle has the potential to minimize the incidence of neurovascular and salivary complications, avoid creating facial scars and opening the articular capsule, and reduce patient morbidity. A minimally invasive protocol for intraoral condylectomy based on precise 3D treatment planning, a reduced incision, and customized piezoelectric surgical instruments has been described herein. The results of the proof-of-concept evaluation

suggest that this technique allows reliable and accurate condylar resection and is technically simple and fast, and that patient morbidity is minimal. This alternative approach could become the treatment of choice for most condylar hyperplastic conditions.

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Competing interests

None.

Ethical approval

Exempt.

Patient consent

Patient consent was obtained to publish the clinical photographs.

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